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# CHEMICAL COMPOSITION OF POTATOES. V. FURTHER STUDIES ON THE RELATIONSHIP OF ORGANIC ACID CONCENTRATIONS TO SPECIFIC GRAVITY AND STORAGE TIME[1]

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## Introduction

Studies on the storage of potatoes, relating free amino acid (9) and non-nitrogenous acid (6) concentrations to specific gravity and storage time, have been reported previously. For those studies, 1959-crop Maine Katahdins were separated into specific gravity classes after various storage intervals, at which times samples of these classes were analyzed for organic acids. Data on the relative proportions of the sample in each class seemed to indicate that some of the potatoes may have been in different gravity classes at different stages of the storage period. This may have been due to inaccuracies in sampling or in determining the average specific gravity of the sample, — a figure which was used as a basis for assigning the specific gravity ranges of the classes after each storage interval.

The present study, with 1960-crop potatoes, was carried out to determine if the previous results would be corroborated. The work was divided into two parts. In one, the potatoes were first separated into specific gravity classes and then stored under the conditions used in the previous study. In the other, the potatoes were classified after each storage interval, as in the previous study, but were stored under conditions which differed from those used in that study. A discussion of the relationships between specific gravity and the nitrogenous constituents in general has already appeared as part of this study (2).

## Materials and Methods

For part one, Katahdin potatoes (1960-crop) grown at Aroostook Farms, Maine, were separated by immersion in glycerol solutions of different concentrations into high, intermediate, and low specific gravity levels immediately after harvest. A description of the separation and sampling procedures has been published (2). After separation, samples from each specific gravity level were placed in individual boxes, stored at 38 F in Maine, and then sent to Philadelphia at different intervals for analysis. After eight months storage at 38 F the potatoes were kept a month longer at 45 F followed by one more month at 50 F to induce sprouting.

For the second part of the study New York-grown Katahdins were obtained from the El-Ge Potato Chip Company in York, Pennsylvania. As in the case of the 1959-crop potatoes, each sample was brine-separated into specific gravity classes just before analysis. After two months storage at 60 F, the storage temperature was gradually lowered over a 30-day period to 38 F. During the last week of the total seven-month storage period the temperature was raised to 56 F.

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For both parts of the study two random samples of the tubers from each specific gravity class were taken at the end of the various storage periods and these samples were then analyzed for acids and solids. Sprouts appeared on the Maine Katahdins after ten months storage. The sprouts from all three specific gravity classes were combined and analyzed in the same manner as the tubers. Acids were determined by separation on ion-exchange columns followed by titration (5, 7).

## Results and Discussion

The results are shown in Tables 1 and 2. The percent of solids listed in these tables differ slightly from those appearing in the previous paper (2) because they represent a sub-set of the larger group of samples covered by that paper.

Table 1.—*Effect of specific gravity and storage*[1] *on acid content of Maine Katahdin potatoes.*

| Months Stored | Solids % | Micromoles acid[2] per gram potato (Dry basis) GLUT | ASP | PYRO | MAL | CIT | PHOS | OXAL | UNID[3] |
|---|---|---|---|---|---|---|---|---|---|
| | | HIGH SPECIFIC GRAVITY CLASS (> 1.086) | | | | | | | |
| 0 | 23.9 | 17.9 | 14.3 | 22.3 | 14.8 | 81.7 | 30.8 | 10.4 | 6.07 |
| 1 | 23.0 | 19.0 | 22.2 | 15.7 | 25.1 | 88.2 | 30.8 | 10.0 | 5.69 |
| 4 | 22.6 | 21.8 | 28.6 | 18.0 | 20.9 | 91.1 | 33.6 | 9.1 | 5.94 |
| 6 | 23.1 | 23.3 | 26.1 | 14.3 | 18.7 | 92.3 | 32.4 | 9.8 | 6.81 |
| 8 | 23.0 | 20.3 | 28.0 | 14.6 | 13.9 | 89.9 | 34.9 | 10.8 | 6.42 |
| 10 | 23.7 | 24.2 | 26.4 | 18.9 | 13.6 | 93.2 | 33.4 | 13.4 | 7.35 |
| | | MEDIUM SPECIFIC GRAVITY CLASS (1.080-1.083) | | | | | | | |
| 0 | 21.6 | 20.9 | 18.3 | 18.0 | 15.7 | 82.7 | 33.8 | 11.2 | 8.66 |
| 1 | 20.9 | 19.1 | 25.1 | 19.4 | 23.6 | 90.0 | 36.3 | 12.8 | 5.51 |
| 4 | 20.8 | 20.3 | 31.0 | 26.5 | 17.2 | 96.6 | 36.9 | 11.8 | 6.41 |
| 6 | 20.8 | 22.0 | 31.3 | 16.4 | 15.9 | 104.8 | 43.0 | 17.4 | 7.80 |
| 8 | 21.0 | 21.1 | 25.4 | 20.0 | 14.5 | 88.4 | 42.5 | 11.6 | 7.01 |
| 10 | 21.6 | 26.6 | 31.0 | 36.7 | 15.6 | 97.0 | 40.0 | 11.6 | 6.72 |
| | | LOW SPECIFIC GRAVITY CLASS (< 1.077) | | | | | | | |
| 0 | 20.3 | 22.0 | 20.1 | 26.7 | 16.9 | 87.0 | 36.7 | 13.4 | 6.65 |
| 1 | 18.5 | 17.8 | 35.0 | 29.2 | 28.5 | 97.2 | 43.1 | 13.6 | 6.59 |
| 4 | 18.2 | 22.7 | 33.0 | 19.2 | 22.5 | 99.2 | 44.5 | 12.2 | 6.68 |
| 6 | 18.0 | 23.3 | 34.6 | 29.4 | 16.2 | 102.1 | 45.3 | 14.0 | 7.54 |
| 8 | 18.3 | 21.8 | 28.2 | 17.4 | 15.5 | 97.8 | 44.5 | 25.2 | 7.48 |
| 10 | 18.8 | 28.3 | 38.8 | 28.3 | 13.6 | 101.4 | 46.1 | 16.3 | 7.34 |
| | | SPROUTS | | | | | | | |
| 10 | 12.7 | 21.9 | 18.5 | 58.9 | 152.6 | 35.4 | 121.8 | 53.9 | 14.6 |
| Coefficient of variation | | 5.8 | 9.7 | 25.0 | 9.4 | 2.9 | 5.0 | 25.2 | 9.6 |

[1]Temperature was changed during storage. See "Materials and Methods."
[2]GLUTamic, ASPartic, PYROglutamic, MALic, CITric, PHOSphoric, OXALic.
[3]UNID = unidentified acid, in milliequivalents percent.

TABLE 2.—*Effect of specific gravity and storage*[1] *on acid content of New York Katahdin potatoes.*

| | | Micromoles acid[2] per gram potato (Dry basis) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Months Stored | Solids % | GLUT | ASP | PYRO | MAL | CIT | PHOS | OXAL | UNID[3] |
| HIGH SPECIFIC GRAVITY CLASS[4] | | | | | | | | | |
| 2 | 21.9 | 25.2 | 35.0 | 16.0 | 17.4 | 121.2 | 20.8 | 9.2 | 10.13 |
| 3 | 22.1 | 25.6 | 35.4 | 18.5 | 21.5 | 123.7 | 24.1 | 16.8 | 7.09 |
| 5 | 21.4 | 31.2 | 32.1 | 18.8 | 28.9 | 113.0 | 26.7 | 14.4 | 7.72 |
| 7 | 22.8 | 23.9 | 29.5 | 16.0 | 16.1 | 129.3 | 24.7 | 15.9 | 7.59 |
| MEDIUM SPECIFIC GRAVITY CLASS[4] | | | | | | | | | |
| 2 | 19.6 | 24.1 | 36.0 | 20.8 | 19.3 | 126.7 | 24.0 | 14.4 | 8.23 |
| 3 | 20.2 | 23.8 | 36.4 | 18.7 | 23.3 | 133.7 | 22.6 | 15.6 | 6.30 |
| 5 | 19.9 | 26.9 | 31.1 | 21.6 | 27.5 | 126.9 | 28.7 | 15.3 | 10.27 |
| 7 | 20.4 | 20.1 | 30.0 | 17.0 | 17.8 | 134.3 | 24.3 | 16.7 | 6.90 |
| LOW SPECIFIC GRAVITY CLASS[4] | | | | | | | | | |
| 2 | 18.0 | 21.8 | 31.9 | 24.3 | 24.3 | 125.0 | 26.5 | 16.8 | 7.45 |
| 3 | 17.9 | 21.6 | 34.2 | 20.2 | 33.4 | 124.3 | 31.1 | 17.0 | 6.54 |
| 5 | 18.3 | 26.6 | 31.1 | 23.2 | 30.9 | 115.2 | 27.8 | 13.2 | 9.23 |
| 7 | 18.4 | 22.8 | 33.0 | 20.8 | 24.8 | 147.1 | 29.1 | 20.0 | 8.11 |
| Coefficient of variation | | 5.3 | 5.3 | 7.5 | 9.0 | 4.6 | 8.0 | 14.0 | 14.4 |

[1]Temperature was changed during storage. See "Materials and Methods."
[2]GLUTamic, ASPartic, PYROglutamic, MALic, CITric, PHOSphoric, OXALic.
[3]UNID = unidentified acid, in milliequivalents percent.
[4]Actual specific gravities were taken each month. Variations caused some overlapping (2).

The percentage of acids was calculated on both a fresh- and dry-weight basis and both sets of results were treated statistically by analysis of variance. The degrees of significance between means of acid concentrations for the different storage periods and specific gravity classes were determined by Duncan's Multiple Range Test (1). The coefficient of variation (the percentage of the mean represented by the standard deviation) was calculated for each acid as a measure of extraneous variation not due to change with specific gravity or storage class.

The anion-exchange method used to determine the non-nitrogenous acids also gave results for three nitrogenous acids — glutamic, aspartic, and pyroglutamic. These are included with the other acids in Tables 1 and 2. The pyroglutamic acid is, at least in part, an artifact derived from glutamine.

In the following discussion of results, changes in acid concentration with storage time or specific gravity, unless otherwise noted, will be mentioned only when found to be significant by the Multiple Range Test at the five percent level. The complete results of this test will be furnished upon request.

*Relation of acid concentration to storage time* —

In previous work with Maine Katahdin potatoes (6) it was found that glutamic, pyroglutamic, aspartic, malic, and citric acid concentrations changed most rapidly the first two months of storage, resulting in some cases in a maximum or minimum concentration after this time. Present results for Maine Katahdins calculated on a dry basis (Table 1) confirm this for aspartic and malic acids, both showing a sharp rise the first month. Following its initial rise, malic shows a decline until the ninth month, the overall change being quite similar to that previously reported. Although changes in pyroglutamic are not statistically significant for the eight- month period at 38 F, the decrease occurring the first month is sharper than any change in the following two- or three-month intervals. Variation in concentration of the unidentified acid is also sharpest the first month although the magnitude of that change is not significant.

Glutamic acid concentration increases slightly during the period of the second through sixth month and more sharply the last two months. Citric acid increases until the end of the sixth month, decreases, and then increases again the last two months. The behavior of glutamic and citric acids apparently does not conform to that previously reported for these acids, but this may be due to the fact that results in this study were not obtainable for the second and third months of storage, — a period close to that in which glutamic and citric concentrations had changed most rapidly.

Phosphoric acid shows a slight rise the first six months; the unidentified acid increases between the first and seventh months; oxalic acid shows no significant change. These results correspond fairly well with past results except that the previous change of phosphoric acid was greater.

When data for the above are calculated on a fresh basis and examined statistically, the corresponding relationships are the same as for the dry basis, except that the increase in aspartic and pyroglutamic acids noted for the final two months of storage and the decrease in the unidentified acid during the first month are significant.

In general it may be said that for the Maine Katahdins, in spite of the difference in the time of separating the potatoes into specific gravity fractions, the behavior of most of the acids is similar to that previously reported. In the case of the exceptions, glutamic and citric acids, the apparent dissimilarity could be partly due to the lack of data for the second and third month of storage. The New York Katahdins would not necessarily be expected to give results similar to those obtained from the 1960-crop Maine Katahdins because of differences in time of getting specific gravity fractions, in storage conditions, and in growing conditions. However, the results are roughly similar for the comparable storage periods — two to seven months. The following changes (New York Katahdins, dry basis) are statistically significant: Glutamic acid shows a rise the fourth and fifth month of storage and then a drop the last two months. Aspartic acid decreases in concentration the fourth and fifth month; pyroglutamic acid decreases during the last two months. Malic acid increases until the end of the fifth month and then decreases. Phosphoric and oxalic acids show no significant change.

Corresponding relationships calculated on a fresh-weight basis are the same except that the change in pyroglutamic acid is not significant. Also, phosphoric acid shows a significant rise the third and fourth month, and the overall increase in oxalic acid is significant.

*Relation of acid content to specific gravity* —

Acid concentration has a relation to specific gravity similar to that previously reported when results are calculated on a dry basis. As shown by the Multiple Range Tests most of the acid concentrations (aspartic, pyroglutamic, citric, phosphoric, and oxalic for the Maine potatoes, pyroglutamic, malic, and phosphoric for the New York) vary inversely with specific gravity. This is what would be expected from Metzger's finding (4) that starch content of potatoes increases more sharply than non-starch content as specific gravity increases. Also for the New York Katahdins, citric gives a consistent inverse relation although not large enough to be statistically significant, and glutamic a direct relation.

Results on a fresh-weight basis are not as clear-cut. In the Maine potatoes glutamic, malic, and citric acids have a direct relation to specific gravity, phosphoric an inverse. Results for the New York potatoes are the same except that aspartic also shows a direct relation and that the phosphoric relation is not significant. Notable is the fact that on a dry basis most of the acid concentrations, including that of citric, vary inversely with specific gravity, but on a fresh-weight basis citric and glutamic vary directly. The strong direct relation of citric acid concentration to specific gravity on a fresh-weight basis was also noted for the 1959-crop potatoes. If the data are calculated on a dry-weight basis, it appears that low-solids potatoes contain more citric than high-solids potatoes. However, if the citric acid content is expressed on a fresh-weight basis, it is seen to be higher in high-solids potatoes. The amount of citric acid present in potatoes of different specific gravities is of particular importance in connection with interpretation of certain data on after-cooking blackening (3).

*Acid concentrations in sprouts* —

As in the case with the 1959-crop potatoes, the pattern of acid concentrations in the sprouts was quite different from that in the tubers. As before, the sprouts contained much more phosphoric and oxalic acids and less aspartic and citric. But, the change in pyroglutamic, malic and the unidentified acid was opposite in direction to that experienced with the 1959 crop. This difference was especially pronounced in the case of malic acid. Whereas previously the sprouts contained only about one third the malic acid concentration of the tubers from which they were taken, this time they contained almost ten times as much.

## Summary

A study of the relation of acid content to specific gravity for both Maine and New York Katahdin potatoes (1960-crop) indicated that on a dry basis the concentration of most of the acids including that of citric varied inversely with specific gravity. On a fresh-weight basis more of the acids varied directly, with citric acid showing a particularly strong direct relationship. These results corroborated previous work with 1959-crop Maine Katahdins, especially the finding that on a fresh-weight basis high specific gravity, and therefore high solids, potatoes had a higher citric acid content.

Data on the change in acid content with storage time agreed only

partly with the 1959-crop data, possibly because results for the second and third months of storage could not be obtained in the present study.

As with the 1959-crop, sprouts contained much more phosphoric and oxalic acids and less aspartic and citric acids than the tubers. However, changes in the concentrations of some of the other acids differed in direction for the two crops.


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